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Evolution of the circumstellar disc of α Eri

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Abstract. The $H\alpha$ line emission formation region in the circumstellar disc of α Eri is: a) extended with a steep outward matter density decline during low $H\alpha$ emission phases; b) less extended with rather constant density distribution during the strong $H\alpha$ emission. The long-term variation of the $H\alpha$ emission has a 14-15 year cyclic $B \rightleftharpoons Be$ phase transition. The disc formation time scales agree with the viscous decretion model. The time required for the disc dissipation is longer than expected from the viscous disc model.

1. Characteristics of the $H\alpha$ line emitting region from 1991 to 2002

The $H\alpha$ line of α Eri was observed several times from 1991 to 2002, in particular, halfway through the epoch of the interferometric observations reported by Domiciano de Souza et al. (2003). The 1999 line profile is used to represent the photospheric absorption and subtracted from all observed $H\alpha$ emission lines. The ‘neat’ $H\alpha$ line emission components are shown in Fig. 1.

The source function S of the $H\alpha$ line in α Eri is dominated by radiative ionization and recombination processes of atomic levels so that its dependence with the optical depth is (Mihalas 1978): $S_{H\alpha}(T_{\text{eff}}, \tau) = \eta^{1/2} B^*$ for $\tau \leq 1$, $\eta^{1/2} B^* \tau^{1/2}$ for $\tau > 1$, where τ_o is the optical depth in the central wavelength of the line; η is the radiative ‘sink’ term; B^* is the ‘source’ factor dependent on photoionization and recombination rates. Using the ring-model described in Arias et al. (2005, this issue) and Vinicius et al. (2005) to represent the $H\alpha$ emission line formation we derive the parameters given in Table 1: τ_o , R_r/R_o (ring radius); H/R_* (semi-height of the ring); V_Ω^r (average ring rotation velocity); V_{rad} (average ring expansion velocity); β form the particle density distribution $N \sim R^{-\beta}$. The fits of the $H\alpha$ line emission component are also shown in Fig. 1. In all cases, a non negligible ring/disc effective height $H/R_* \sim 3.4 \pm 0.6$ is required. The line profiles in 1991, 1998 and 2002 require on average quite extended emitting regions $\langle R_E/R_o \rangle \simeq 40$ and outward steeply decreasing density distributions: $\beta \sim 2$. The emitting region of $H\alpha$ from 1993 to 1995 is $\langle R_E/R_o \rangle \simeq 11 \pm 3$ with nearly the same disc height $\langle H/R_* \rangle \simeq 3.6 \pm 0.1$ and a quite uniform density distribution: $\beta \sim 0$.

2. Cyclic long-term $H\alpha$ line emission changes

We can take advantage of observations that we obtained on the $H\alpha$ line emission changes from 1991 to 2002, to derive some information on the time scales that

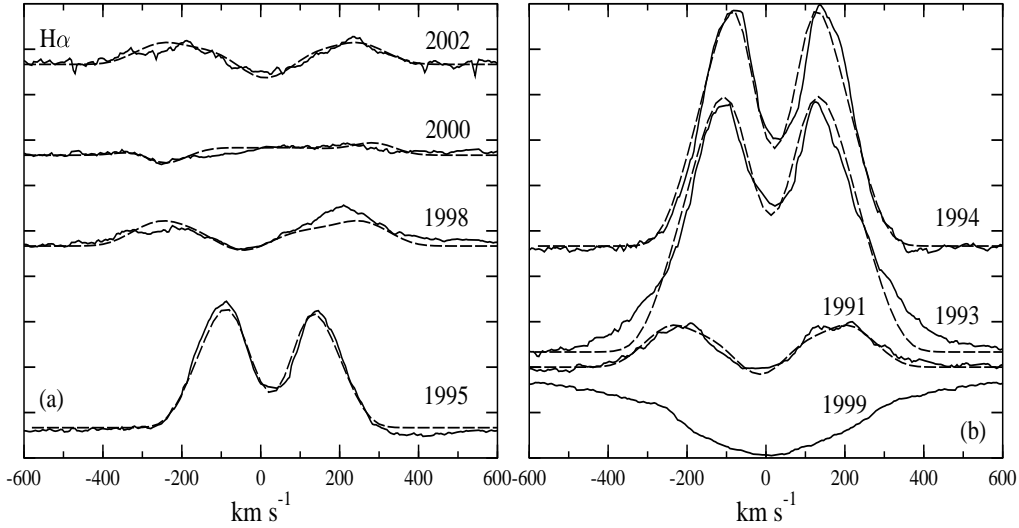


Figure 1. $H\alpha$ line profiles from 1991 to 2002. These profiles have the photospheric line component (1999) subtracted, so that the continuum level is set to zero. Observed profiles are in full lines and model fits are in dashed lines. The scale of intensities I/I_o is 0.15

Table 1. Circumstellar disc parameters from fits of $H\alpha$ emission line profiles

Epoch	τ_o	R_r/R_o	H/R_*	V_Ω^r	V_{rad}	β
1991	0.15	3.8	3.8	265	0	1.8
1993	1.18	6.0	3.5	197	0	0.2
1994	0.70	5.9	3.8	185	0	-0.1
1995	0.25	5.5	3.5	190	-10	0.1
1998	0.09	3.8	3.5	275	50	2.0
2000	0.08	3.8	2.2	220	255	-0.4
2002	0.13	3.7	2.5	270	-15	1.9

characterize a complete cycle of $B \rightleftharpoons Be$ transition. We also compare this cycle with the long-term $H\alpha$ variations in α Eri observed in previous epochs. The time scales of these cycles matter to understand the disc formation mechanisms (Porter 1999, Okazaki 2001). We collected in the literature the spectroscopic and photometric records of the $H\alpha$ line variation and studied them as a function of time.

The variation of the equivalent width of the $H\alpha$ line emission component before 1991 is shown in Fig. 2a. In this figure we also added the qualitative estimates of the emission intensity noted in the literature before 1965. The changes of the $H\alpha$ emission observed from 1991 to 2002 is shown in Fig. 2b. From both panels in Fig. 2 we conclude that there is a sort of cyclic variation of the the $H\alpha$ line emission. The maxima of emission are attained each 14 years roughly, while the onsets of the increase towards the greatest emission maxima produce about each 15 years. Fig. 2 shows that the two last B-normal like aspects lasted 4 to 5 years. From the last two cycles we learn that after the

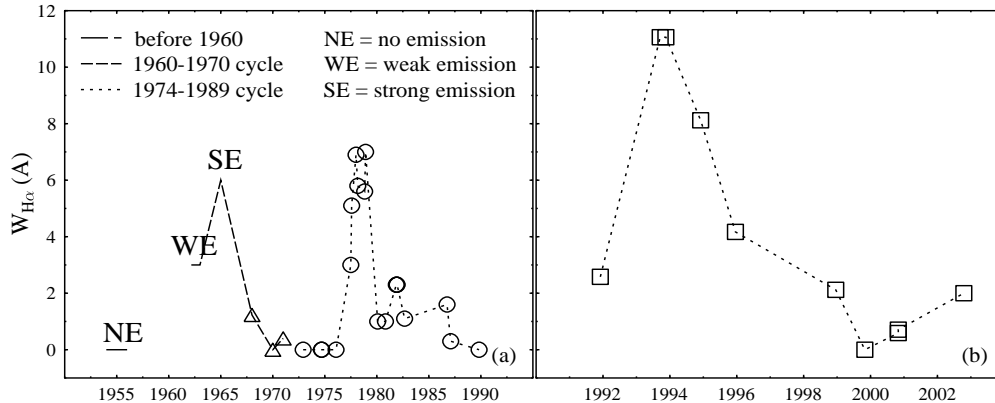


Figure 2. Long-term variation of the equivalent width W in Å of the $H\alpha$ line emission. (a) Qualitative estimates of the emission strength (NE = no emission; WE = weak emission; SE = strong emission) and quantitative equivalent widths before 1990 collected in the literature. (b) New equivalent widths obtained in this work after 1990

quiescent, or B-normal like phases, the star resumes its maximum emission in no more than 2 years. We can also see that after each emission maxima there is a 4-5 year lasting plateau of weak emission before the star recovers the B-normal like aspect. These time scales may have some significance to model the CE formation in this star.

If the evolution of the CE in α Eri, i.e. formation and subsequent dissipation, has to be understood in terms of a viscous decretion disc model (Porter 1999, Okazaki 2001), from the expected average viscous time scales for $t \sim 60/\alpha$ days (Clark et al. 2003), we would derive two quite different series of values for the viscosity coefficient α . The time scales implied by the CE formation, estimated from the time that takes the emission rise in the $H\alpha$ line: 2 years roughly, we would obtain $\alpha \sim 0.08$, which is of the same order as expected for CE envelopes studied by Blondin & Negueruela (2001), Matsumoto (1999) and Clark et al. (2003). The time required by the decrease from maximum to zero is either 10 years in the 1974-1989 cycle or 6 years during the 1991-2000 cycle. This imply $0.02 \lesssim \alpha \lesssim 0.03$, which is about 4 times smaller than implied in the formation process. We may then wonder whether the bulk redistribution of material in the circumstellar disc occurs only as a consequence of a viscous redistribution of angular momentum.

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